Geophysical Research Abstracts, Vol. 9, 05836, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05836

Groundwater assessment and management of excess surface water for sustainable use of an alluvial coastal aquifer in eastern India

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Groundwater use in developing countries such as India has been increasing rapidly in recent decades due to an expansion of irrigation agriculture. This often leads to a decline in groundwater levels resulting in a range of environmental problems. In the coastal plain of Orissa, India these problems are largely associated with saltwater intrusion, which leads to a reduction in the groundwater quality and thus the irrigation water quality.

In order to find ways for sustainable groundwater use regarding groundwater quality and water demand for irrigation, a regional-scale assessment of the groundwater resources and a field-scale investigation was conducted to manage excess surface water during the monsoon season and the implication on the regional-scale.

The main focus of this study is to extend the concept of sustainable groundwater management in coastal alluvial aquifers using seasonal subsurface water storage by ASR-wells (**a**quifer **s**torage and **r**ecovery). The formulation for the groundwater budget was extended by including a term for managed aquifer recharge to incorporate ASR-wells:

$q_{nr} = \Delta S - q_e + q_{in} - q_{out} + q_{mar} - q_w$ (1)

where q_{nr} is the natural recharge in mm/a, ΔS the changes in subsurface storage (mm/a), q_e groundwater withdrawal due to capillary rise (mm/a), q_{in} the subsurface inflow (mm/a), q_{out} the subsurface outflow (mm/a), q_{mar} the managed aquifer

recharge (mm/a) and q_w the groundwater withdrawal (mm/a).

The groundwater flow was calculated by Darcys law, the withdrawal were collected at the Central Groundwater Board and the withdrawal due to capillary rise was calculated. The groundwater recharge q_{nr} was determinate using the WTF method (**w**ater-**t**able **f**luctuation). The WTF-method is based on the assumption that the groundwater table rise in an unconfined aquifer is caused by groundwater recharge, and described by the following equation:

$q_{nr}= n_{eff} * \Delta h/\Delta t$ (2)

where n_{eff} the effective porosity (-), h the hydraulic head (m), t the time (a). The method was extended for confined groundwater systems by adding an exponential function:

$\Delta h(t) = h_o*exp(-(t-t_o)/k)*\int(h_{at}(\tau)*1/k*exp(-(t-t_o)/k))\, d\tau$ (3)

where k is a constant (a), h_{at} is the head in an aquitard (m), the subscript "$_o$" indicates the initial conditions and τ is an integration variable.

The results showed that current recharge is significantly larger than recharge prior to agricultural expansion because of rice cultivation (98% of the agricultural land in monsoon season), and in particular, seepage from small dyke's constructed for holding water around the fields. A strong association was found between an increasing groundwater recharge and land use. The actual mean groundwater recharge by rainfall is 217 mm/a. Surface water systems contribute 19 mm/a of recharge.

Due to the raising groundwater withdrawal for irrigation, groundwater levels are declining in some areas; other areas are at high risk of overexploitation since withdrawals are approaching rates of recharge. Therefore a groundwater management system based on seasonal subsurface storage of excess surface water during the monsoon season was developed which has the potential to expand the sustainable groundwater storage which can be used for irrigation. The concept was tested in a field study in Kharagpur, eastern India and shows an average potential infiltration capacity of nearly 450 mm/a.